

An innocent bystander's view of what's new in GENIE 10

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DUNE LB PWG 11/24/2015



All GENIE 10 info from S. Dytman/G. Purdue/C. Andreopoulos
Gabe will give talk at next ND working group meeting I think

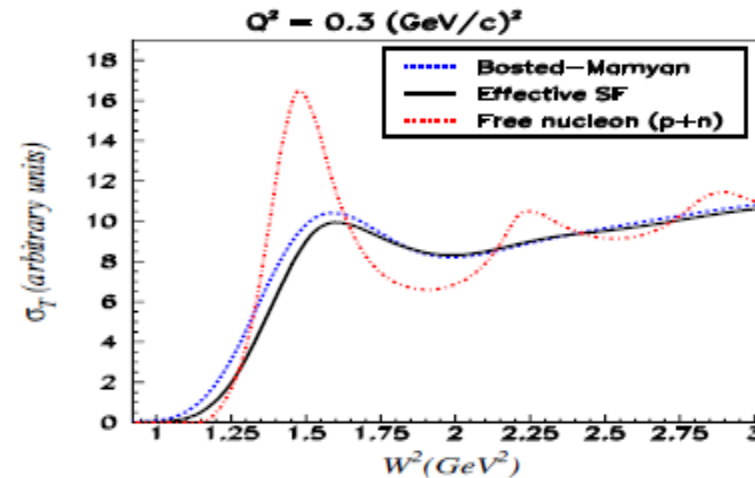
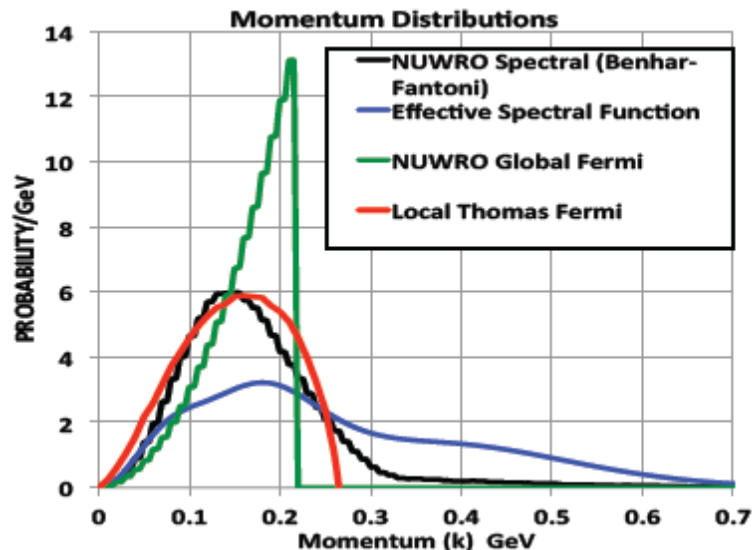
From GENIE experts (G. Purdue, S. Dytman, C. Andreopolous)
(mostly from Costas' NUINT GENIE talk)

Default settings and tuning are unchanged

- Model introduction release for GENIE 10:
 - Effective Spectral Functions from A. Bodek, E. Christy, B. Coopersmith (EPJC (2014) 74:3091). (B. Coopersmith and A. Bodek, URochester)
 - Very-High Energy extension (5 TeV, working toward PeV) (K. Hoshina, Wisconsin)
 - Inclusive Eta production. (J. Liu, W&M)
 - New Berger-Sehgal resonant pion production model, tuned with MiniBooNE data by J. Nowak. Berger, Sehgal Phys. Rev. D76, 113004 (2007) & Kuzmin, Lyubushkin, Naumov Mod. Phys. Lett. A19 (2004) 2815 (J. Nowak (Lancaster), I. Kakorin (JINR) and S. Dytman)
 - Improved hA FSI model. (S. Dytman and N. Geary)
 - Single Kaon production model by Alam, Simo, Athar, and Vacas (PRD 82, 033001 (2010)). (C. Marshall and M. Nirkko, Rochester and Bern)

effective spectral functions

- Bodek, Christy, Coopersmith, [hep/ph: 1405.0583](#)
- Create “effective spectral functions” - give good fits to quasielastic e scattering data $(1/\sigma)(d\sigma/d\nu)$ for the 2014 ψ' superscaling function at Q^2 values of 0.1, 0.3, 0.5, 0.7.
- Modify with correction at low Q^2 to reduce nucleon removal energy.
- Effective spectral function includes more than the initial state.
- 2p2h processes (short range correlations, transverse enhancement (MEC)) and FSI are included in the initial state effective spectral function
- Fermi motion effects in resonance and deep inelastic regimes done in fashion similar to Bosted and Mamyan ([arXiv: 1203.2262](#)), with probability function taken from the effective spectral function.

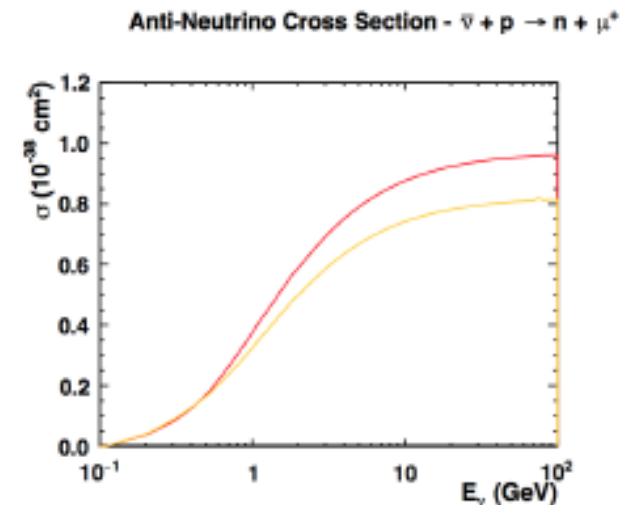
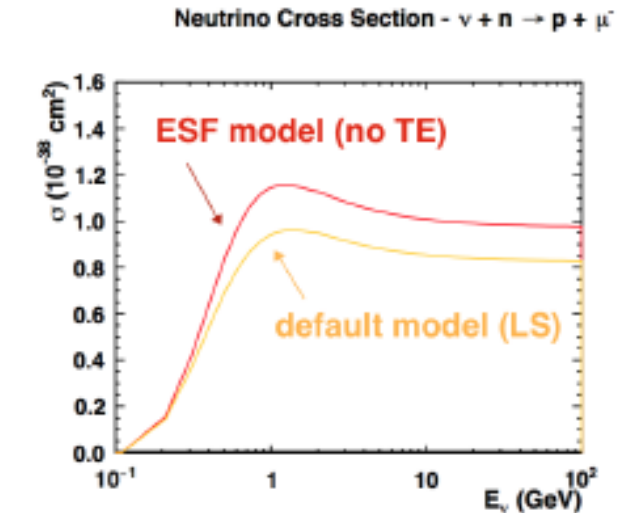


Figs. From Bodek, Christy, Coopersmith, [hep/ph: 1405.0583](#)

C. Andreopoulos:

- Superscaling calculations (PRC 71 (2005) 015501) include FSI effects responsible for an increase of strength in the tail of the differential cross-section distribution and a decrease in the peak. The **Effective Spectral Function (ESF)** model (Bodek, Christy and Coopersmith, EPJC 74 (2014) 3091) included in 2.10.0 is fitted to the superscaling models predictions.
- 2.10.0 also includes the **Transverse Enhancement Model (TEM)** (can be enabled separately within the ESF model) where Q^2 dependent modifications to the elastic proton and neutron magnetic form factors simulate nuclear effects like those expected from MEC.

Implemented by B. Coopersmith.



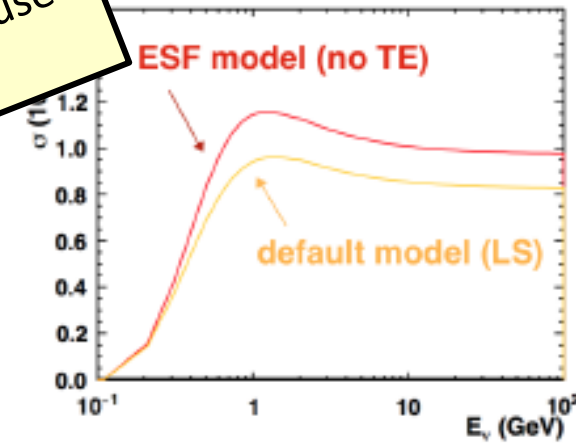
C. Andreopoulos:

- Superscaling calculations (PRC 71 (6) 015501) include FSI effects + increase of strength in cross-section at the peak.

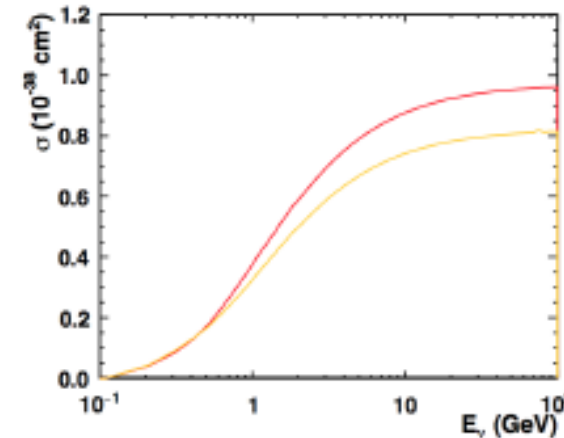
Valencia 2p2h model not in this version of GENIE but is being implemented by J. Schwehr, D. Cherdack, R. Gran and should be included in the next model release update (I think). Do not use blindly with ESF/TEM since they effectively include 2p2h.

- 2.10.0 also includes the **Transverse Enhancement Model (TEM)** (can be enabled separately within the ESF model) where Q^2 dependent modifications to the elastic proton and neutron magnetic form factors simulate nuclear effects like those expected from MEC.

Neutrino Cross Section - $\nu + n \rightarrow p + \mu^-$



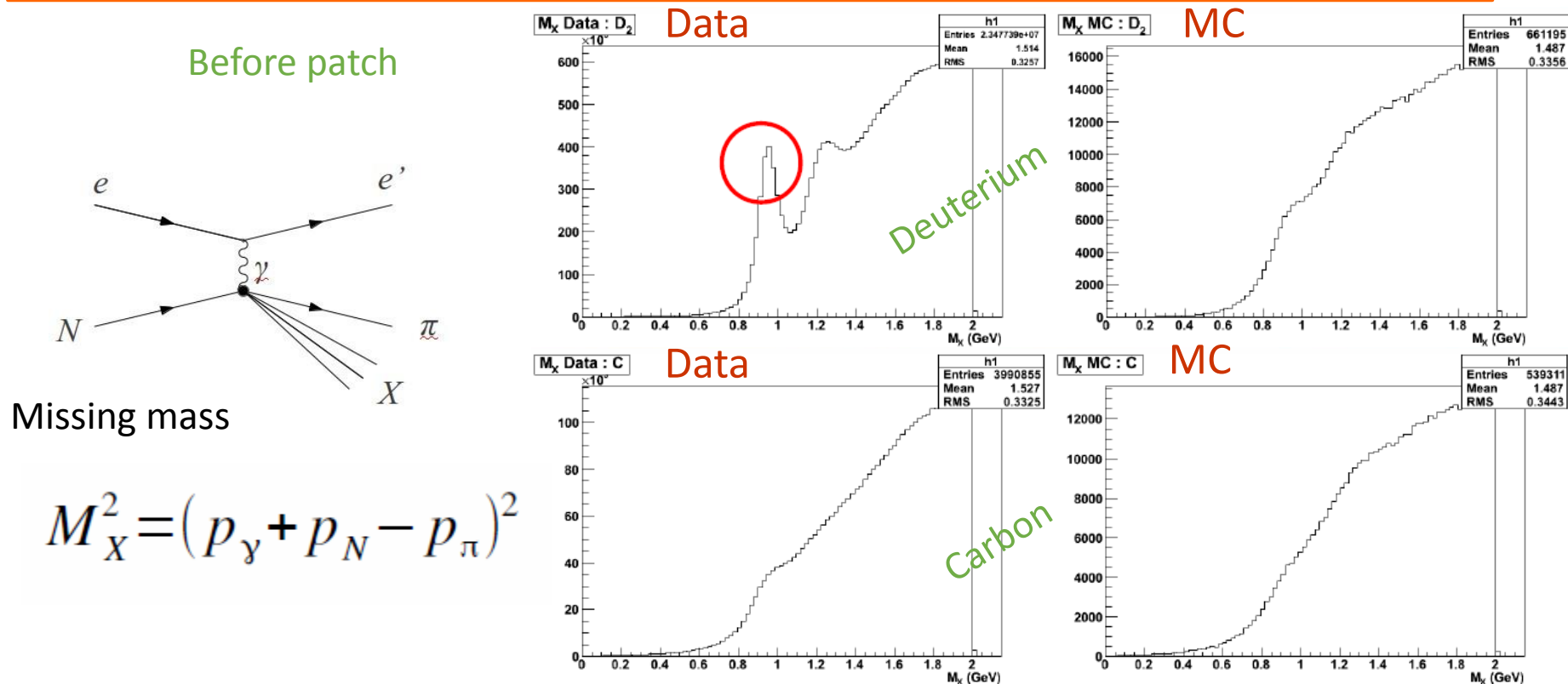
Anti-Neutrino Cross Section - $\bar{\nu} + p \rightarrow n + \mu^+$



Implemented by B. Coopersmith.

Effective spectral function model includes a new deuterium model

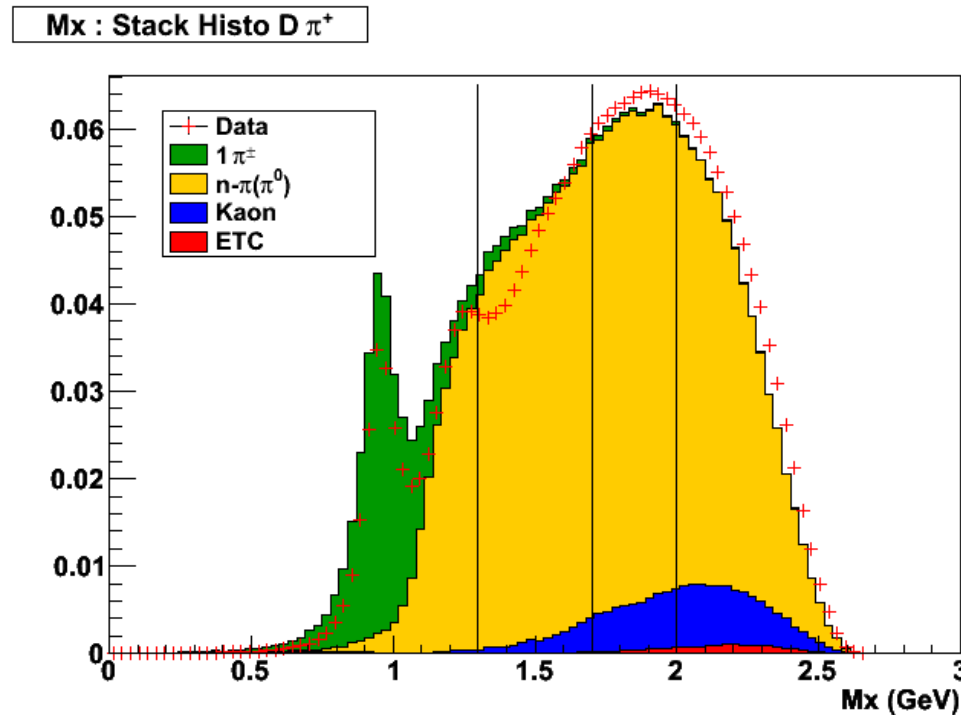
- Significant data-MC disagreement in missing-mass plots for D_2 traced to use of Li Fermi gas constant in GENIE 2.8.1 D_2 nuclear model.
- Put patch in GENIE 2.8.1 using new D_2 model (incorporated with the effective spectral functions from Bodek, Christy, Coopersmith). New D_2 model comes from fit to theoretical calculations from paper in preparation by Christy, Kalantarians, Ethier, and Melnitchouk.



Using new deuterium model in GENIE eA

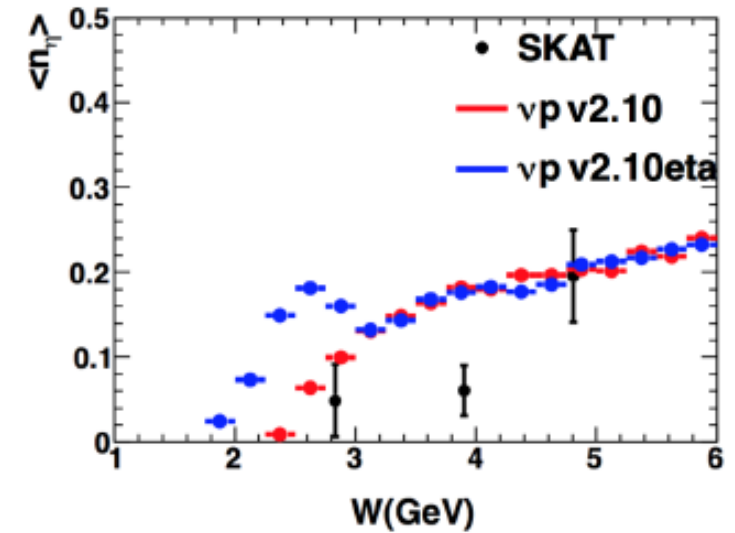
- Significant improvement in the data-MC agreement in missing-mass plots for D_2 with implementation of effective spectral functions, including the fit to calculations from Christy et al.

After patch



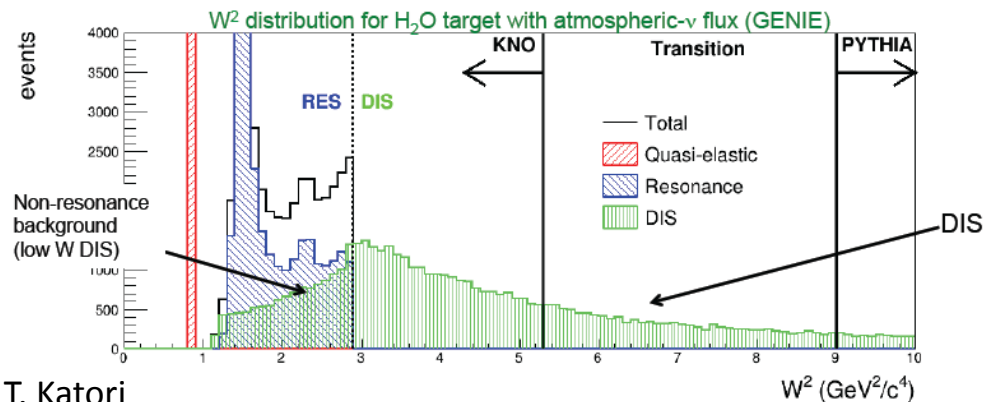
From C. Andreopoulos

- η production important for ν_e appearance as η 's have purely electromagnetic decays into photons.
- η 's were produced by resonance decays and by the PYTHIA model, but not by the KNO-based part of the AGKY hadronization model.
- Kinematic gap in η production.
- Added option to generate $\eta\eta$ and $\eta\pi^0$ pairs with some probability (untuned).



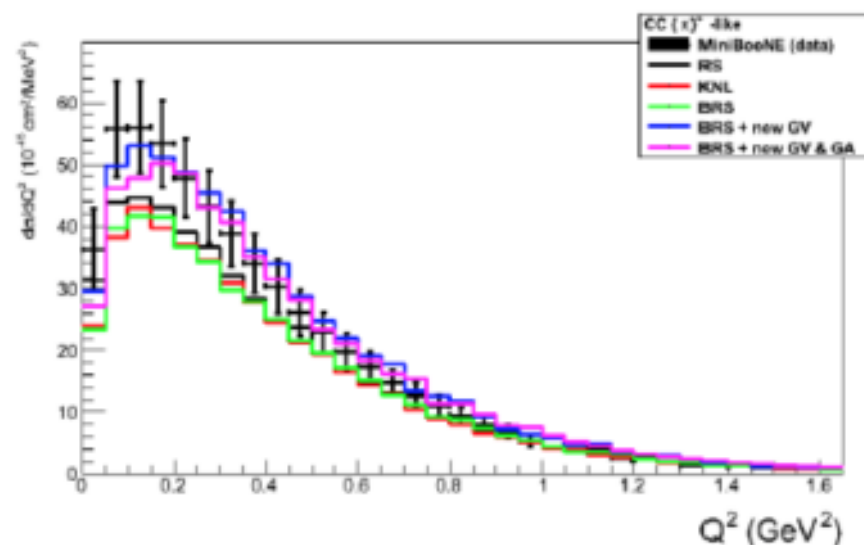
η production rate measurements from the SKAT experiment, compared with the GENIE default prediction (red) and the GENIE prediction with eta production parameters set to large non-zero values (blue).

Implemented by J. Liu.



From T. Katori

- New resonance models
 - Kuzmin-Lyubushkin-Naumov (KLN) model (MPL A19 (2004)) 2815)
 - Berger-Sehgal (BS) model (PRD 76, 113004 (2007))
- KLN similar to Rein-Sehgal (RS), but includes muon mass effects.
- BS similar to KLN, but includes the pion pole contribution.
- Both models include new vector and axial form factors by the MiniBooNE Collaboration (AIP Conf.Proc. 1189 (2009) 243-248)



Comparison with MiniBooNE $\text{CC}\pi^+$ data. The plot shows the effect of adding the components of the model one at a time.

Implemented by J. Nowak, I. Kakorin and S. Dytman.

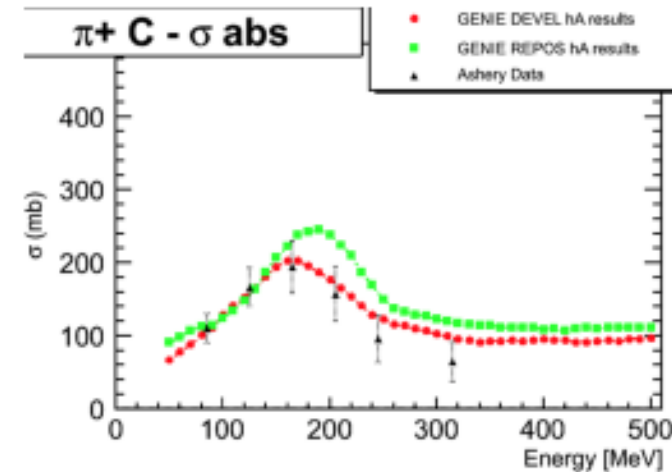
Updated hA FSI model

Recall that GENIE includes two intranuclear hadron transport models:

- *INTRANUKE/hA*: effective model anchored on data (default)
 - We parameterize a cascade with one *effective* interaction.
 - The model is a) easily re-weightable, and b) in good agreement with data.
- *INTRANUKE/hN*: full INC model (alternative)

Previously hA used data on Fe^{56} and A scaling ($A^{2/3}$ dependence, but this doesn't agree well with data).

- Now including π scattering data for Li^7 , C^{12} , Al^{27} , Fe^{56} , Nb^{93} and Bi^{209} (less extrapolation needed).
- Now absorption scales as $A^{2/3+0.18}$, charge exchange as $A^{2/3}$, elastic as $A^{2/3+0.25}$, inelastic as $A^{2/3}$, and pion production as $A^{2/3}$. The total cross-section scales as $A^{2/3}$.



Implemented by N. Geary and S. Dytman

Single kaon production

From C. Andreopoulos

Implemented by C Marshall and M. Nirkko

Single Kaon production:

- $\nu_\ell + p \rightarrow \ell^- + K^+ + p$
- $\nu_\ell + n \rightarrow \ell^- + K^0 + p$
- $\nu_\ell + n \rightarrow \ell^- + K^+ + n$

A new ($\Delta S = 1$) process in GENIE. Previously only associated production ($\Delta S = 0$) was simulated.

Based on the model of Alam, Simo, Athar, and Vacas (PRD 82, 033001 (2010)).

CM is Rochester student doing a thesis on NC K⁺ production with MINERvA

Neutral-current reactions like

- $\nu p \rightarrow \nu K^+ \Lambda$
- $\nu n \rightarrow \nu K^+ \Sigma^-$

are backgrounds in searches for $p \rightarrow K^+ \nu$



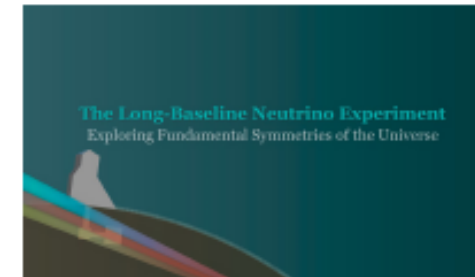
$$p \rightarrow K^+ \nu \text{ at DUNE}$$



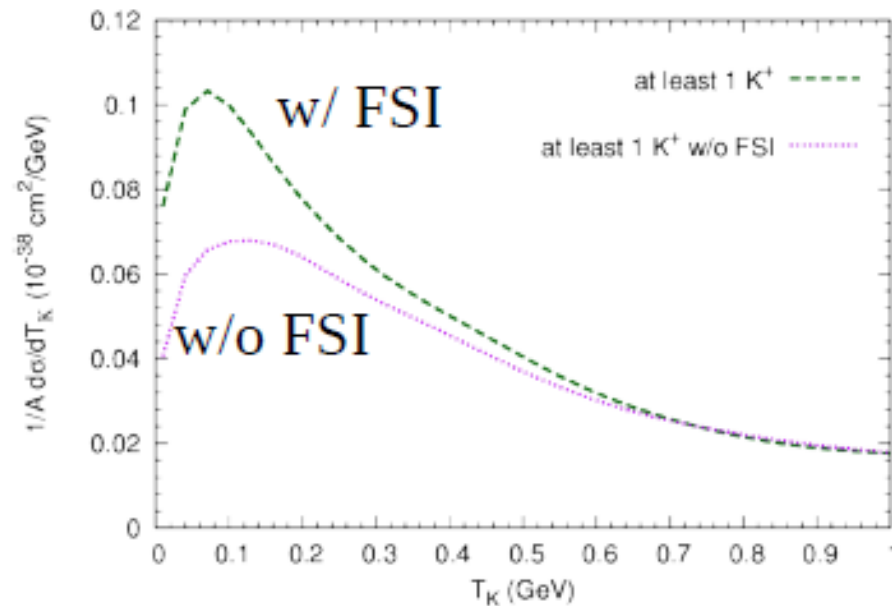
“If it can be demonstrated that background processes mimicking this signature can be rejected at the appropriate level, a single $p \rightarrow K^+ \nu$ candidate could constitute evidence for proton decay.”

“...it is natural to ask to what extent simulations are capable of providing reliable estimates for such rare processes. What if the actual rate for single-kaon atmospheric-neutrino events is higher by a factor of ten or more? Is that even conceivable?”

DUNE/LBNE science document, Chapter 5



- MINERvA can benchmark the Monte Carlo with a measurement of the NC K^+ rate
- MINERvA can measure the K^+ kinetic energy spectrum in CC and NC events, which is sensitive to interactions final-state particles inside the nucleus (FSI)



GiBUU CC K^+ production with and without FSI

U. Mosel, O. Lalakulich, and K. Gallmeister, Phys. Rev. D 89, 093003 (2014)

So ... Chris put single kaon production in GENIE ...

- Many new models on the way
- GENIE 2.10 contains many bug fixes and some technical changes
- GENIE 2.10 is a model introduction release and does not have a new tune or new default settings

See NUINT 2015 talk by Costa Andreopoulos for more details